# PATENT SPECIFICATION

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## (54) IMPROVEMENTS IN DYNAMO-ELECTRIC MACHINES INCLUDING ADHESIVELY BONDED COMMUTATORS

(71) We, GENERAL ELECTRIC COMPANY, a corporation organised and existing under the laws of the State of New York, United States of America, of 1 River Road, Schenectady 12305, State of New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention pertains to dynamo-electric machines including commutators which are less expensive and easier to manufacture in mass production than those heretofore available.

A large majority of d-c motors and generators, particularly those intended for industrial use, include as an important component thereof a cylindrical rotating commutator having a plurality of spaced apart segments on the outer surface thereof, each of the segments being capable of conducting a substantial amount of electrical current and therefore being of relatively large mass. In operation, these segments are subject to substantial centrifugal force as the commutator rotates. This centrifugal force must be resisted in order to maintain the integrity of the structure. For this purpose, various forms of mechanical restraining means are generally utilized. These restraining means may take the form of shrunken rings or glass bands at several positions around the periphery of the commutator or shoulders or dovetails in the commutation segments with mating retaining shoulders in the commutator base.

Another less generally used form of mechanical restraining means is made by molding the commutator base with the commutation segments imbedded therein. In commutators of this type, the commutation segments generally include an expanded base portion or shoulder to facilitate restraint of movement of the segment by the base member in which it is imbedded.

These prior art mechanically bound commutator assemblies share certain serious disadvantages. First, the mechanical design of these commutation segments, to provide for the mechanical restraining means, is longer in the radial dimension and complex in shape. In fact, a trapezoidal cross section is generally used to provide adequate width on the outer surface of the segments and adequate spacing between segments at their inner end. The cost of these segments is therefore excessive.

Secondly, typical prior art commutators are difficult to assemble with the segments in properly spaced relationship. The criticallity of this spacing is seen from the fact that in the assembly of commutators for most industrial type dynamoelectric machines now manufactured, these commutator segments are placed individually by hand into a commutator assembly fixture and mica spacers, also individually placed by hand in the assembly, are used to set and maintain the spacing between the commutation segments. This assembly technique is a major factor in the cost of conventional prior art commutators.

To some extent, the prior art also includes other types of commutator assemblies. For example, in small motors, a disc commutator, in which thin copper foil commutation segments are adhesively bonded to the planar face of a disc base, has been suggested. Such a construction is clearly limited to very small motors in view of the limited current carrying capacity of foil. Further, in a disc construction a relatively large amount of bonding surface facilitates the adhesive bonding means, as does the small mass of the foil commutation segments. Centrifugal forces exerted by commutator segments for industrial motor applications can be significantly higher than in prior art foil type commutators. These centrifugal forces can be expressed in lbs/in$^2$/mil of copper. Typical forces for industrial type commutators range from 0.1 to 0.6 lbs/in$^2$/mil of copper. The current carrying capacity of industrial type commutators is significantly higher than that of prior art foil type commutators. Examples are included.

| Commutator | lbs/in²/mil of Copper | Mils of Copper | lbs/in² | Current (amps) |
|---|---|---|---|---|
| Industrial A | .36 | 280 | 100 | to 25 |
| „ B | .45 | 1 020 | 460 | to 40 |
| „ C | .21 | 1 410 | 306 | to 360 |
| „ D | .21 | 3 125 | 656 | to 3000 |

It is therefore the general object of the present invention to provide dynamoelectric machines having a commutator assembly suitable for industrial type dynamoelectric machines which assembly is less expensive and more easily manufactured than those heretofore available.

The present invention is a dynamoelectric machine comprising an armature commutator including a base member having a cylindrical outer surface and a shaft mouting means along the axis thereof, a coating of alumina on the cylindrical outer surface of said base member, a plurality of metallic commutation segments circumferentially spaced at equal intervals about said coating on the base member, each of said segments extending lengthwise of said base member and having an essentially flat bonding surface adjacent and tangent to the outer surface of said coating, and a non-metallic, non-conductive, highly dielectric adhesive layer interposed between each of said segments and said coating for bonding said coating and said commutation segments bonding surfaces, said layer being co-extensive with said bonding surfaces.

In the preferred embodiment of the present invention, specific epoxy and polyimide adhesive resins are used to bond copper, aluminium or zinc-coated copper commutation segments to an electrically insulated cylindrical base member.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

FIGURE 1 is a perspective view of an armature for a typical industrial-type dynamoelectric machine according to the present invention;

FIGURE 2 is a cross sectional view of the commutator assembly shown in FIGURE 1;

FIGURE 3 is a perspective view of the commutator segment used in the assembly of FIGURE 1;

FIGURE 4 is a perspective view of one typical type of prior art commutation segment;

FIGURE 5 is a perspective view of another typical type of prior art commutation segment; and

FIGURE 6 is a perspective view of an apparatus for automatically assembling the commutator assemblies.

Referring more specifically to FIGURE 1 there is shown an armature assembly 10 for an industrial-type dynamoelectric machine, including specifically armature coils 12, armature shaft 14 and a commutator assembly which includes an alumina coated cylindrical base member 16 and commutation segments 18 mounted thereon. The ends 18*a* of the segments are in electrical contact with armature coils 12 through lead wires 12*a*.

A commutator assembly is provided in which commutation segments are fastened onto the base member 16 through the use of the full surface area of these commutation segments which is in contact with the alumina coating on the surface of the base member 16. By making use of the full surface area for the purpose of attaching the commutation segments 18 to the base member 16, the stress which is produced on the commutation segments 18 as the armature assembly 10 rotates is thus distributed over the full surface area of these commutation segments.

In contrast, the prior art commutation segments, such as those shown in FIGURES 4 AND 5, have a resulting high stress concentration built up at various corners of these segments because the bands or molding compounds used to hold these prior art segments in place tend to restrain the commutation segments against movement by opposing centrifugal force over a relatively small area of these segments. By providing a commutator assembly which inherently has a substantially uniform stress distribution over the surface of the individual commutation segments, it is possible to substantially decrease the amount of copper which is used in the manufacture of each of these segments, to increase the mechanical stability of the commutator assembly, and to simplify the construction of the commutator assembly.

The commutator assembly in FIGURE 1 is seen in cross section in FIGURE 2 wherein there is shown specifically rotating base member 16 and a commutation segment 18. As seen in FIGURE 3, in which is shown, perspectively, metallic commutation segment 18, each of the segments in the commutator assembly shown in FIGURE 1 is of relatively simple shape with a rectangular cross section. This is in contrast to the trapezoidal shape of the typical prior art commutation segments shown in FIGURES 4 and 5, which it will be noticed are also of complex side shape in order to provide a dovetail 22, in FIGURE 5, and seats 24 for glass bands, in FIGURE 4.

The complex shape and trapezoidal cross section of typical prior art commutation segments, as seen in FIGURES 4 and 5, render such segments expensive and difficult to produce. Moreover, such segments generally must be hand placed and assembled using mica spacers to maintain the proper intersegment distance. This further adds to the expense and complexity of conventional prior art commutators.

In contrast the commutator assembly described herein may be easily mass produced in that the segments of this assembly may be simultaneously positioned and secured to the commutator base member. One form of apparatus for that purpose is illustrated in FIGURE 6. More specifically, there is shown apparatus including a shaft 26 for mounting base member 16 of the commutator structure to be assembled. Means are provided in the apparatus base 28 for rotating shaft 26 through a precise predetermined arc set, for example, by an arc-divider not shown. The base member 16 and shaft 26 may be rotated through a predetermined arc of a circle by any of several devices manufactured for this purpose. These devices include manually operated dividing heads, ratchet-type indexers, cam or air operated devices or numerical tape control systems. The apparatus also includes an overhead support 32 from which is suspended a commutator segment supply and delivery means 34 adapted to move downward and position a commutation segment 18 on base member 16. Means are also provided for activating an adhesive layer interposed between commutation segment 18 and the alumina coating on base member 16. This activation means may comprise resistance heating leads, an ultrasonic generator, or some other type of energizing device, disposed at the lower end of commutation segment supply and positioning means 34. The adhesive activation means may also comprise some type of energizing such as heating the base member 16. Dials 30 and 36 may be mounted on base 28 for controlling the arc divider and adhesive activating means.

In operation, the apparatus of FIGURE 6 functions in the following manner. A base member 16 is mounted on shaft 26 so that the alumina coated cylindrical outer surface of base member 16 is directly below commutation segments supply and positioning means 34. Adhesive is applied either to the coated cylindrical outer surface of base member 16 or by applicator means in commutation segment positioning and supply means 34 to the lower surface of commutation segment 18 at the lower end of supply and positioning means 34. Supply and positioning means 34 is then lowered automatically to bring commutation segment 18 into contact, through the interposed adhesive layer, with base member 16 and activation energy is supplied to promote the bonding of segment 18 to the coating on base member 16. Positioning and supply means 34 then releases commutation segment 18 and moves back up to its starting position while the rotating means in apparatus base 28 turns shaft 26 through a precisely predetermined arc corresponding to the desired intersegment distance of the final commutator assembly structurt. The sequence is then repeated until shaft 26 has been rotated through 360° and commutator segments have been bonded at equally spaced intervals about the circumferential periphery of base member 16. The assembled commutator structure is then removed from shaft 26 and is ready for assembly into the armature of a dynamoelectric machine.

Many adhesives require a cure after initial activation to bring about ultimate bond strength. This cure may be effected by removing the commutator assembly from the assembly apparatus, temporarily securing all of the segments via mechanical bonding means in their bonded position and placing the entire assembly in an oven. Tape or rings may be placed around the assembled segments to secure the segments to the base member during this post-curing stage. The temperature and time of cure is of course dependent on the particular adhesive.

In commutator assemblies intended for specific applications, it may be desirable to provide other means to assist the adhesive bond in restraining segments from movement with respect to the base member. For this purpose, bands may be placed on the commutator in areas where they do not interfere with the brush track, such as at either end of the commutator or between brush tracks. However, the bands or other restraining means which may be used in this manner are not of themselves adequate to hold the commutation segments onto the base member 16 without the adhesive bond.

Where a problem is observed with respect to a tendency on the part of the commutation segments 18 to peel from the base member 16, the use of these bands may be sufficient to prevent the start of the peeling action near the end of the commutation segments 18, such as near the end which is located away from

the remaining portion of the armature assembly 10. Further, slots may be machined on the circumference of the bonded commutator for placement of the bands. Generally, machining may be done by a standard Carboloy tool. The commutator surface should also be machined in one of the conventional manners.

Other methods of assembling the commutator structure of the present invention will also be apparent to those skilled in the art. One such alternative is to position all segments about the circumference of the commutator base member simultaneously, with an adhesive layer interposed between the coated base member and the segments and then simultaneously applying activation energy to effect the adhesive bond. Because of the difficulty of precisely positioning a multiplicity of commutator segments and holding these segments in these precisely determined positions for the bonding operation, this method of assembly is somewhat difficult. For this reason, this particular method of assembling the bonded commutator structure of the present invention may not be as practical as that described above.

The various elements of the commutator assembly of the dynamo-electric machine of the present invention may be comprised of a variety of materials treated in a variety of ways.

As seen in Fig. 2, the base member 16 is of steel and is provided mith a plasma sprayed alumina outer coating 17.

The steel base members 16 may be prepared, for example, by molding, turning, cutting or grinding. Generally, the outer surface of the base member is sandblasted or roughened in some way prior to the application of the insulating alumina coating thereto.

The commutator segments used in the present invention may be made from rectangular or bevelled metal stock. Generally, they are made of copper or a copper alloy selected for specific properties, although aluminum and other metals may be used. When rectangular cross section stock is used, rounded or radiused edges are provided on the bonding surface thereof to minimize stress concentration at the outer limits of this bonding surface. If the segment is made of copper, generally it is degreased with solvent and then acid (bright) dipped to ensure bonding of the segment to the base member. In some cases, it may be desirable to have a thin layer of zinc diffused on the surface of the copper segment. Among other things, this may improve the bondability of the copper segments. Such a layer may be provided by degreasing with solvent, acid bright dipping, cyanide cleaning, plating the copper segments with zinc and then diffusing the zinc into the copper by heat treating it at 200—250°C.

Depending on the assembly method used, the commutator segments may then be coated on their bonding surface with the adhesive to be used or delivered directly to the assembly apparatus. Alternatively, the adhesive may be applied to the copper segment in the assembly apparatus or it may be applied to the base member to which the segments are to be bonded. This may depend, among other things, on the design of the assembly apparatus and the assembly procedure used. Generally, if heating is used to provide the adhesive activation energy, and if the base member is heated, the adhesive is supplied to the commutator segment. Conversely, if the commutator segment is heated, the adhesive is applied to the base member. If some other form of activation energy is used such as ultrasonic heating or radiant heating, for example, the adhesive may be applied either to the commutator segments or to the base member.

The adhesive is generally applied as a viscous liquid and a roller, liquid dispenser, or spray form of application may be used. Such viscous liquid adhesive also includes a spacing filler, such as glass beads, to keep the adhesive from being squeezed out from between the segment and mounting surface thereby starving the bond interface of adhesive material. Alternatively, adhesives disposed in a sheet-type supply means can be applied by wrapping the sheet around the alumina coated commutator base member. Hot melt adhesives may be applied by spray, electrostatic, or fluid bed techniques and combinations of these techniques can also be applied to hot melt adhesives

The details of the various adhesive compositions which may be used will be described below.

Adhesive used to provide the bonding layer in the commutator structure must be capable of providing a high strength bond between a metallic segment and the alumina surface of a rotating base member. Further, the adhesive must be non-conductive and have good dielectric strength. The former characteristic is necessary to avoid arc-over between commutation segments at the base thereof due to adhesive material around the commutation segments while the latter characteristic is necessary to avoid voltage-induced breakdown of the adhesive material due to voltage differentials between commutation segments and the rotating base element to which the segments are mounted. Further, it is desirable that the adhesive be capable of withstanding high temperatures since such temperatures are often encountered in larger d-c motors and generators. Of course, the adhesive must also have good aging characteristics.

While this invention is not limited to any particular adhesive or classes of adhesives, certain resin families, and particular examples thereof, have been found to be particularly effective in the commutator structures disclosed herein. These include, specifically, cer-

tain heat cured epoxies and polyimides. Such polyimides include those designated as FM34 and a siloxane imide. According to the American Cyanamid Company literature, FM34 is a polyimide adhesive supported by a glass carrier and containing a filler containing an arsenic compound. According to our analysis, the resinous portion is comprised of the reaction product on an aromatic dianhydride and aromatic diamine. The siloxane imide is described in U.S. Patent No. 3,325,450.

Specific epoxides which have been found to be useful include (1) a diaminodiphenylsulfone-cured poly-glycidol ether of tetraphenyl ethane including a fine aluminum powder filler, (2) a polyanhydride cured polyglycidol ether of bis-phenol A, and (3) a borontrifluoride monoethylamine and polyethylene glycol mixture cured cycloaliphatic epoxide resin. The first of these, which is commercially available from the Goodyear Company as Plastilock 677, has been analyzed in our laboratories. According to our analysis, Plastilock 677 comprises approximately 55—60% of Epon 1031 epoxy resin (commercially available from the Shell Chemical Company), approximately 20% of diaminodiphenylsulfone, approximately 1% of a Lewis acid type catalyst such as boron trifluoride monoethylamine and 20—25% of a fine aluminum powder. The second of the foregoing epoxies, which is commercially available as Eccobond 104 from Emerson & Cuming, Inc., was also analyzed in our laboratories. According to our analysis, it comprises approximately 50—55% of an epoxide such as Epon 828 epoxy resin (commercially available from the Shell Chemical Company), 1.5—2.5% carbon filler and 40—45% of pyromellitic dianhydride combined with certain fillers and pigments not included in the foregoing material concentration calculations.

In Table 1 below, there are listed several typical adhesives, together with their source and type, which have been tested in a bonded commutator assembly, as disclosed herein. These test assemblies had a radius of 2.125 inches and a commutator segment weight of $1.64 \times 10^{-2}$ pounds. In each case the structure was tested either by high rate of revolution or high temperature or both. The commutators were not restrained by glass bands during the tests.

TABLE 1

| Comm. No. | Adhesives (Commercial Designation) | Adhesive Chemical Type | Adhesive Source | Spin Test rpm | Spin Test °C |
|---|---|---|---|---|---|
| 1 | DK4 Powder | Anydride Cured Epoxide Resin | Hysol Corporation | 6000 | 25 |
| 2 | Formula A | Cycloaliphatic Epoxide Resin | | 6000 | 25 |
| 3 | Formula B | Siloxane Imide | U.S. Patent No. 3,325,450 | 1600 | 25 |
| 4*a* | Formula C | Cycloaliphatic Epoxide Resin | | 6000 | 220 |
| 4*b* | Plastilock 677 | Amine Cured, Phenolic Modified Epoxide Resin | Goodyear Company | 6000 | 220 |
| 4*c* | Eccobond 104 | Anhydride Cured Epoxide Resin | Emerson & Cuming, Inc. | 6000 | 240 |
| 4*d* | Epon 958 | Filled Epoxide Resin | Shell Chemical Company | 6000 | 150 |
| 4*e* | Epon 951 | Amine Cured Epoxide Resin | Shell Chemical Company | 6000 | 150 |
| $4^9$ | HT 424 | Amine Cured Phenolic Epoxide Resin | American Cyanamid Company | 6000 6000 | 150 |
| 4*g* | Plastilock 677 | Amine Cured Epoxide Resin | Goodyear Company | 6000 | 110 |
| 4*h* | FM34 | Polyimide | American Cyanamid Company | 6000 | 110 |

Adhesive formula A is comprised of 87 to 94% of a material similar to CY—179 which is an epoxy resin made by Ciba Chemical Company, 1 to 3% boron fluoride monoethylamine which is made by Allied Chemical Corporation, 2 to 6% Carbowa 400 which is made by Union Carbide Chemical Company and 1 to 4% pyrogenic colloidal silica which is made by Cabot Corporation. Adhesive formula C is similar to formula A except that the pyrogenic silica is excluded.

Reference is made to our copending application No. 41613/71 (Serial No. 1361830) which also relates to dynamoelectric machines having commutators.

WHAT WE CLAIM IS:—

1. A dynamoelectric machine comprising an armature commutator including a base member having a cylindrical outer surface and a shaft mounting means along the axis thereof, a coating of alumina on the cylindrical outer surface of said base member, a plurality of metalic commutation segments circumferentially spaced at equal intervals about said coating on the base member, each of said segments extending lengthwise of said base member and having an essentially flat bonding surface adjacent and tangent to the outer surface of said coating and a non-metallic, non-conductive, highly dielectric adhesive layer interposed between each of said segments and said coating for bonding said coating and said commutation segments bonding surfaces, said layer being co-extensive with said bonding surfaces.

2. A dynamoelectric machine as claimed in

Claim 1, wherein the cross-sectional shape of said segments in a plane perpendicular to the length thereof is generally rectangular.

3. A dynamoelectric machine as claimed in Claim 1 or Claim 2, wherein said base member is comprised of steel with a plasma sprayed alumina outer coating.

4. A dynamoelectric machine as claimed in any preceding claim, wherein said commutation segments are comprised of copper.

5. A dynamoelectric machine as claimed in Claim 4, wherein the commutation segments have a diffused zinc coating on the bonding surface thereof.

6. A dynamoelectric machine as claimed in any of Claims 1 to 3, wherein the commutation segments are comprised of aluminum.

7. A dynamoelectric machine as claimed in any preceding claim, wherein said adhesive layer comprises a cured cycloaliphatic epoxide resin.

8. A dynamoelectric machine as claimed in Claim 7, wherein said cycloaliphatic epoxide resin has been cured with a mixture of borontrifluoride monoethylamine and polyethylene glycol.

9. A dynamoelectric machine as claimed in Claim 1, wherein said adhesive layer comprises a polyanhydride cured polyglycidol ether of bis-phenol A.

10. A dynamoelectric machine as claimed in Claim 1, wherein said adhesive layer is produced by heat-curing a mixture, compressively held between said base member and said commutation segments, said mixture comprising, by weight, 50—55% Epon 828, and 40—50% pyromellitic dianhydride, exclusive of non-reactive fillers and pigments.

11. A dynamoelectric machine as claimed in Claim 1, wherein said adhesive layer comprises a diaminodiphenylsulfone-cured polyglycidol ether of tetraphenyl ethane including 20—25%, by weight, based on the weight of cured resin, of fine aluminum powder.

12. A dynamoelectric machine as claimed in Claim 1, wherein said adhesive layer is produced by heat during a mixture, compressively held between said base member and said commutation segments, said mixture comprising, by weight, 55—60% Epon 1031, approximately 20% diaminodiphenyl-sulfone, approximately 1% of a Lewis acid type catalyst, and 20—25% of fine aluminum powder.

13. A dynamoelectric machine, as claimed in Claim 12, wherein said Lewis acid type catalyst is borontrifluoride monoethylamine.

14. A dynamoelectric machine having an armature commutator substantially as hereinbefore described with reference to, and as illustrated in, Figs. 1 to 3 and 6 of the accompanying drawings.

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1361829 COMPLETE SPECIFICATION

3 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

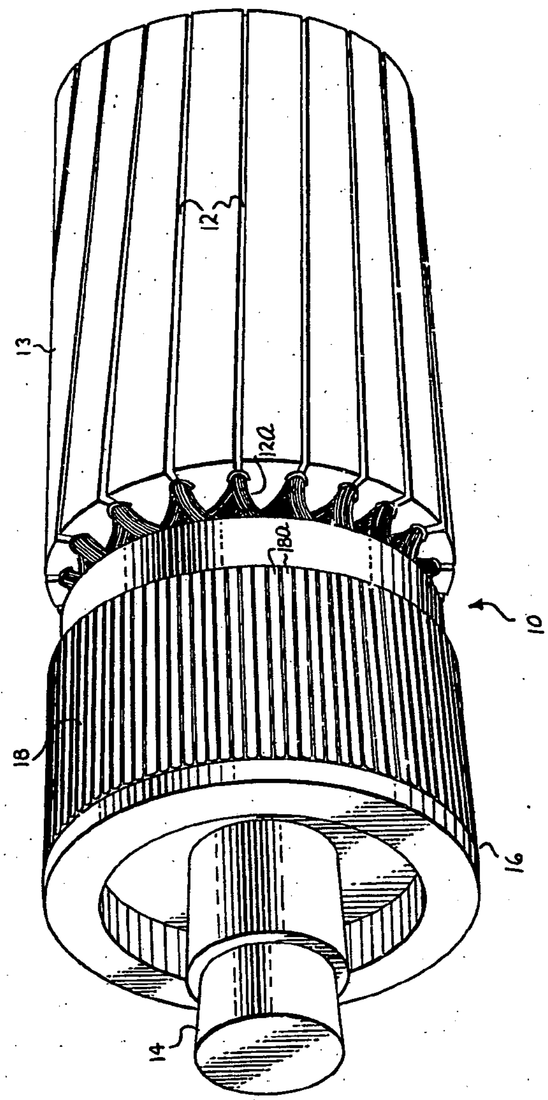


FIG. I

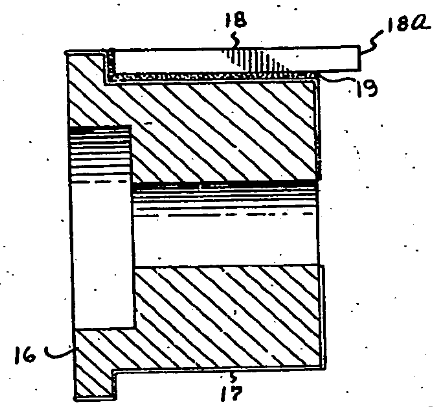


FIG. 2

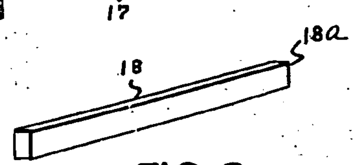


FIG. 3

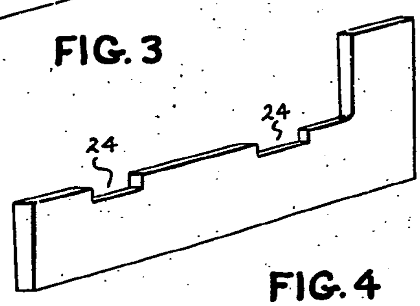


FIG. 4

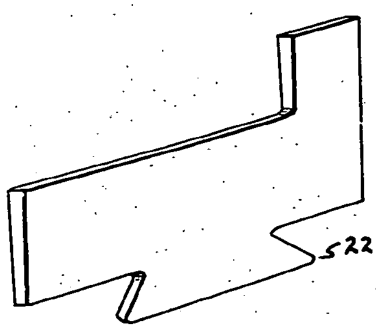


FIG. 5

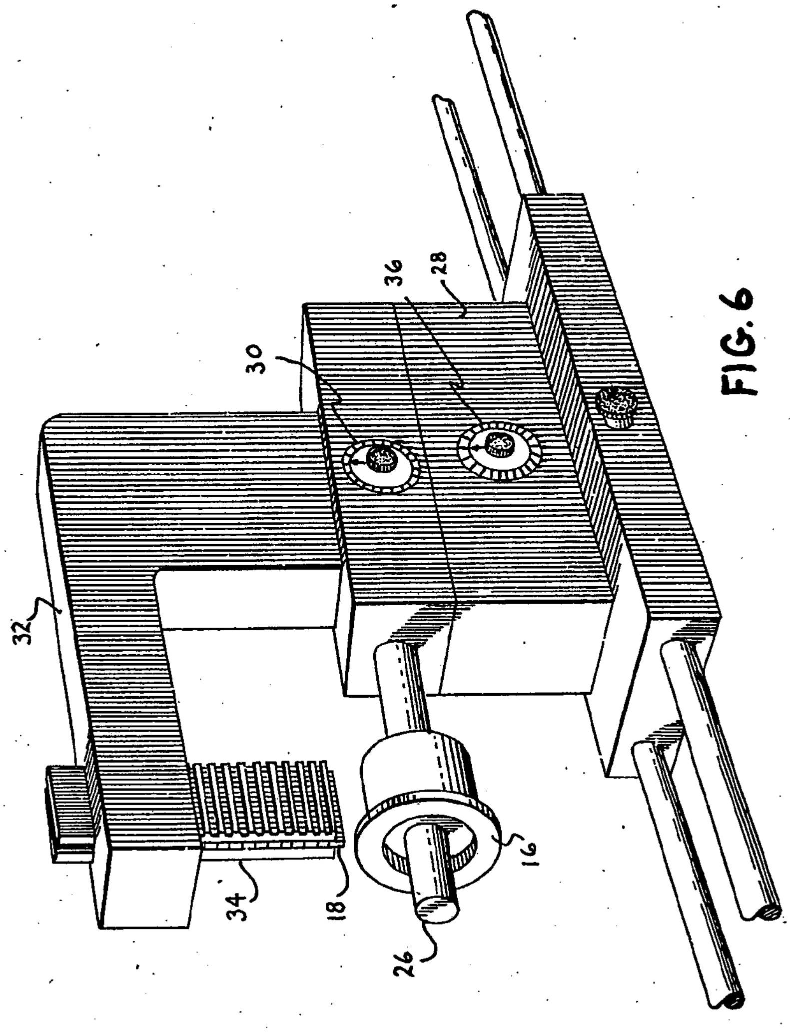


FIG. 6